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High Energy Astrophysics

Third Edition

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For Deborah

Contents

Preface

Ancient history

It was a challenge to write this third edition of *High Energy Astrophysics*. Writing the first edition was great fun and that rather slim volume reflected rather closely the lecturing style I adopted in presenting high energy astrophysics to final-year undergraduates in the period 1973–7. Although the material was updated when the manuscript was sent to the press in 1980, the book remained in essence a lecture course (Longair, 1981). The reception of the book was encouraging and in due course a second edition was needed. The subject had advanced so rapidly during the 1980s and early 1990s that the material could not be comfortably contained within one volume. The aim was originally to complete the task in two volumes, but by the time the Volumes 1 and 2 were completed, I had only reached the edge of our own Galaxy (Longair, 1997b,c)†. Volume 3 was begun, but for various reasons, was not completed – the whole project was becoming somewhat unwieldy.

In the meantime, I completed three other major book-writing projects. The first of these was a new edition of *Theoretical Concepts in Physics* (Longair, 2003). Then, I completed *The Cosmic Century: A History of Astrophysics and Cosmology* (Longair, 2006). Finally, in 2008, the new edition of *Galaxy Formation* was published (Longair, 2008).

The new edition

Since the second edition of *High Energy Astrophysics*, many of the subject areas have changed out of all recognition and new areas of astrophysical research have been opened up, for example, ultra-high energy γ-ray astronomy. The publication of *Theoretical Concepts in Physics*, *The Cosmic Century* and *Galaxy Formation* have made it feasible to condense the original plan of a three volume work into a single volume. In reorganising

† The original volumes of the second edition were first published in 1992 (Volume 1) and 1994 (Volume 2). Major revisions and corrections were included in the 1997 reprints of both volumes. I regard the 1997 reissues as the definite versions of the second edition.

the material, some hard decisions had to be taken, but the convenience of including everything in one volume is worth the sacrifice of some of the material from the second edition. The principal decisions were as follows:

- Much of the relevant historical material has been included in *The Cosmic Century* and so that material will not be repeated here. I make references to the appropriate sections of *The Cosmic Century* and other historical texts. I do this with considerable reluctance since the historical development of High Energy Astrophysics has influenced strongly the way in which the astrophysics has developed intellectually. History will not disappear completely, but it will not be as prominent as in the earlier editions.
- Much of the necessary material needed to obtain a modern view of galaxies and the large scale structure of the Universe is included in *Galaxy Formation*. In particular, there is no need to repeat much of the detailed discussion of galaxies and clusters, or the large scale structure and dynamics of the Universe. These topics are, however, central to many of the topics in this book and so summaries of the most important topics needed to understand the astronomical context of high energy astrophysics are provided in Part 1.
- There was a strong emphasis upon the origin of cosmic rays in the first two editions. I still consider this to be excellent material, particularly in the area of ultra-high energy cosmic rays, but it has been somewhat abbreviated in the new edition.
- There was also a considerable amount of material on detectors and telescopes in the earlier edition. I believe this material is of the greatest interest and importance in understanding our ability of make observations in different wavebands. This aspect of the subject has been strongly moderated in the new edition. These are fascinating topics, but modern telescopes and detectors have become increasingly complex and sophisticated. Summaries of a number of important topics in the physics of astronomical detectors and telescopes are included as an Appendix.
- In the second edition, I devoted some space to high energy astrophysics in the Solar System. This material has been abbreviated, but important topics such as the diffusion of energetic charged particles in the Solar Wind and the acceleration of charged particles in solar flares have been preserved.
- The opportunity has been taken to rationalise the presentation of the physical and astrophysical processes so that duplication of material is avoided.
- The writing has been very considerably tightened up so that the discussion is less discursive than in the earlier editions. Again, I regret the necessity of doing this since often these asides provide valuable physical insights for the reader new to the subject.

The aims of the present edition are the same as the earlier editions. A very wide range of physical processes relevant for high energy astrophysics is discussed, the emphasis being strongly upon the understanding of the underlying physics. I aim to maintain the informal style of the earlier editions and have no hesitation about using the first person singular

or expressing my personal opinion about the material under discussion. The emphasis is strongly upon physical principles and the discussion of general results rather than particular models which may have only ephemeral appeal.

As I learned during the writing of *The Cosmic Century*, physics and astrophysics have a symbiotic relation. On the one hand, the astrophysical sciences are concerned with the application of the laws of physics to phenomena on a large-scale in a Universe. On the other hand, new laws of physics are discovered and tested through astronomical observations and their astrophysical interpretation. In these ways, the new astrophysics, of which high energy astrophysics is one of the most important ingredients, is just as much a part of modern physics as laboratory physics.

Although there is limited scope for deviation from the central theme in this new edition, one of my original aims was to give the reader a feeling of what it is like to undertake research at the limits of present understanding. Astrophysics is fortunate in that many of the fundamental problems can be understood without a great deal of new physics or new physical concepts. Thus, the text may also be considered as introduction to the way in which research is carried out in the astrophysical context.

Above all, however, this material is not only mind-stretching, but also great fun. I have no intention of inhibiting my enthusiasm and enormous enjoyment of the physics and astrophysics for its own sake.

Malcolm Longair
Cambridge and Venice
January 2010.

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There are many people whom it is a pleasure to thank for help and advice during the preparation of this volume. Just as the first edition was begun during a visit to the Osservatorio Astronomico di Arcetri in Florence in April 1980, so the second edition could not have been completed without the Regents' Fellowship of the Smithsonian Institution which I held at the Harvard-Smithsonian Astrophysical Observatory during the period April–June 1990. I am particularly grateful to Professors Irwin Shapiro and Giovanni Fazio for sponsoring this visit to Harvard during which time the final drafts of Chapters 1–10 of the first volume of the second edition were completed. During that period, I had particularly helpful discussions with Drs Eugene Avrett, George Rybicki, Giovanni Fazio, Margaret Geller and many others. I am particularly grateful to them for their advice.

Much of the preliminary rewriting was completed while I was at the Royal Observatory, Edinburgh. Among the many colleagues with whom I discussed the contents of this volume, I must single out Dr John Peacock who provided deep insights into many topics. In completing the final chapter on the high energy astrophysics of the Solar System, I greatly benefitted from the advice of Professors John Brown, Carole Jordan and Eric Priest. Not only did they point me in the correct directions but they also reviewed my first drafts of that chapter. I am especially grateful to them for this laborious task. Many colleagues made helpful suggestions about corrections and additions to the first addition among whom Dr Roger Chevalier provided an especially useful list.

Coincidentally, the writing of the third edition began while I was a visitor at the Osservatorio Astronomico di Arcetri in Florence during the period April to June 2007. I thank Professor Francesco Palla and his colleagues for their hospitality during that visit. The catalogue of friends and colleagues who have continued to contribute to my understanding of high energy astrophysics and astrophysical cosmology since the publication of the second edition is enormous. Many of them are acknowledged in my recent books, but the list is so long that I would be bound to miss someone out. I acknowledge particular insights from my colleagues in the course of the book. Special thanks are due to Dr. David Green for his

expert advice, not only on supernova remnants, but also on the more arcane idiosyncracies of LaTeX.

To all of these friends and colleagues I make the usual disclaimer that any misrepresentations of the material presented in this book is entirely my responsibility and not theirs. Finally, I acknowledge the unfailing support and love of my family, Deborah, Mark and Sarah who have contributed much more than they will ever know to the completion of this book.

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Name Index

Object Index

Index